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STUDY OF OPTICAL SOUND GENERATION AND AMPLIFICATION(U) 1/1

MISSISSIPPI UNIV UNIVERSITY PHYSICAL ACOUSTICS RESEARCH

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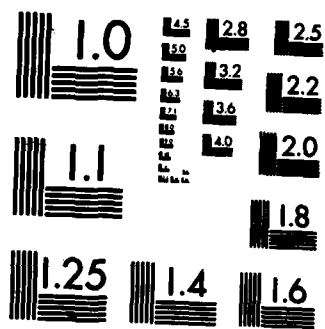
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This project involves four separate tasks with the following titles: Task I Generation of low frequency sound from optical pulses. Task II Propagation of sound through a gas with an overpopulation of vibrationally excited states, Task III Opto-acoustic studies in liquids and Task IV Non linear oscillation of gas bubbles. The first three tasks funded by the physics division of ONR represent a three pronged study of the generation of sound by the absorption of light. The fourth task, funded by the mathematics division of ONR is a continuing study of cavitation in liquids.		

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Study of Optical Sound Generation and Amplification
Annual Report
1 January 1984 - 31 October 1984

by

Henry E. Bass, Lawrence A. Crum and F. Douglas Shields
Physical Acoustics Research Laboratory
The Department of Physics & Astronomy
The University of Mississippi
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General Comments

During the period covered by this contract, the Physical Acoustics Research Laboratory has awarded one Ph.D., one student has completed all requirements for the Ph.D., and two students should complete all requirements by the end of this year. This will leave the laboratory with three Ph.D. candidates and four M.S. candidates. Two Ph.D. students and one M.S. student are not U.S. citizens. All our present Ph.D. students have accepted jobs upon graduation or, in the case of two foreign students, will return to their home institution.

Plans to move the Physical Acoustics Research Laboratory into a renovated space large enough to house all projects is preceding slowly. Estimates of renovation costs exceed \$800,000. Funds of that magnitude have not been identified.



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Task 1

Generation of Low Frequency Sound from Optical Pulses

H.E. Bass

The objective of this task is to generate audible frequency sound from a series of short optical pulses modulated in time and amplitude.

The pulsed spectrophone work is near completion. The study of pressure pulse generation in a nearly transparent gas (CO_2) has been published (see attachment). Measurements of pressure pulse generation in a highly absorbing gas (SF_6) are near completion and will serve as the basis for Mr. Manaf Ali's Ph.D. dissertation (~Aug. 85). Highly absorbing SF_6 more nearly simulates an absorbing fluid or black surface than does CO_2 . A large optical attenuation coefficient does complicate measurements as outlined in the CO_2 paper.

While the mechanism for pressure pulse generation is being studied in gases, we are simultaneously pursuing modulation schemes to produce audible sound. This summer, Dr. Dwyann LaFleur, a visiting professor, used a broad band dielectric speaker driven with short pulses of variable repetition rates and amplitudes to examine audible sound generation schemes. Mr. Ali is now putting together a circuit to modulate the output of a high power strobe lamp using Dr. LaFleur's modulation scheme.

Task II

Propagation of Sound Through a Gas with an Overpopulation of Vibrationally Excited States

F. Douglas Shields

Theoretical studies by Bass and Bauer showed some years ago that a sound wave should be amplified upon passage through a gas with an over population of vibrationally excited states. This task seeks to study this phenomenon(SACER) in a situation that is amenable to experimental measurement i.e. a gas in a metastable excited state that is decaying slowly on the scale of the sound period.

During the past year measurements have been made on N_2 and mixtures of N_2 with He and H_2 . The N_2 is vibrationally excited by an electric discharge. Due to a large collision cross section the electron-molecule collisions in the discharge cause 90% or more of the discharge energy to be deposited in the vibrational mode of N_2 . As a result the N_2 is left with vibrational temperatures in the thousands of degrees while the translational temperature is changed very little.

By terminating the electric discharge on a screen a short distance from the end of the discharge tube, a shock wave is generated at the hot/cold gas junction at the screen. The wave reflects back and forth in the tube and is detected and Fourier analyzed at the end of each round trip. By performing this analysis for different lengths of the discharge (and therefore the sound path) it is possible to get both the sound absorption and sound velocity as a function of frequency.

During the past year this technique has been perfected to the point that we can now use the measured sound velocity to determine the variation of translational temperature of the gas with time after the discharge.

With pure N_2 it has been observed that the discharge changes the temperature very slightly. This discovery was at first a surprise but is now understood. In pure N_2 not enough of the discharge energy gets into translation to produce an observable initial change in translational temperature and the vibrational energy is relaxing so slowly it is being conducted to the walls without raising the translational temperature.

When He or H_2 are added to the N_2 , initial increase in translational temperature is observed due evidently to the fact that the He and H_2 cause more of the discharge energy to go directly into translation. We are now studying the decay of this translational temperature in an effort to extract the vibrational relaxation time and the thermal diffusion time.

Even more exciting, we have now observed and measured the gain in the sound amplitude produced by the relaxing vibrational specific heat. In fact we are also measuring this gain as a function of time and hope to get a consistent measurement of the vibrational relaxation time from this also.

At present we are planning on trying to make measurements on N_2/H_2O mixtures. If successful these measurements would give a much needed value of the temperature dependence of the H_2O/N_2 transition rate.

CO is similar to N_2 in that an electric discharge will also leave

it highly vibrationally excited. However, since CO has a dipole moment it will be possible to observe the variation in vibrational temperature by the radiation from the excited vibrational states. Therefore, we will try to make measurements on this gas next. If it is possible to measure the gain and vibrational temperature simultaneously we will be able to get an accurate test of the theoretical equations reported earlier.

Task 3

Opto-Acoustic Studies of Liquids

H.E. Bass

The goal of this task is to identify the microscopic mechanism for pressure pulse generation when a liquid absorbs a laser pulse. This work is similar to the spectrophone studies in the gas phase except on a much shorter time scale consistent with the shorter time between interactions characteristic of liquids.

Our initial goal is to reproduce the recent work by Tam of IBM. He subjected a liquid to a pulse from a N_2 laser with a pulse length ~ 1 nsec and observed structural relaxation. His electronics limited resolution to a few nsec. Though we now have electronics capable of resolution to 50 psec, we will initially restrict our attention to the 1-100 nsec time regime. In this time regime, we will examine the effect of laser power density on the amplitude of the observed pressure pulse. If Tam was observing structural relaxation, we would expect to see step like behavior as the laser pulse energy becomes sufficient to detach one, two, three, etc. molecules from the cluster. Macroscopically, this would be seen as a non-linear behavior of the thermal expansion coefficient and corresponding improved optical to acoustic conversion efficiency.

The N_2 laser, high speed oscilloscope, probe laser, and optical table have arrived. The high speed (50 GHz) photo-detector was received in August but tests showed that the fiber-optic pigtail was detached from the photo-diode. The assembly has been returned to the manufacturer for repair and recalibration.

Task 4

Nonlinear Oscillation of Gas Bubbles

L.A. Crum

The goal of this task is to examine the dynamics of gas bubble oscillations at large driving amplitudes.

We are pleased to report a dramatic breakthrough. Our consultant theoretician, Andrea Prosperetti, has discovered a mathematical way to describe the bubble oscillations exactly (actually, the approximations made are very good). In order to obtain useable solutions, however, we must numerically solve a set of three coupled equations (2DE's and 1 PDE). We made a crude attempt this fall to obtain a computer code to give us some initial results, and have found them both exciting and troublesome. Exciting because the results indicate that much higher pressures and temperatures are present within the bubble than we had expected; troublesome because the results are not stable, having long transients in them, and so we may have been generating a lot of nonsense. Unfortunately, to write a precise code will take a couple of months, and although we have started work immediately, are disappointed.

We anticipate a flurry of publications once the numerical results are available; however, we now must wait until we are sure of the numbers.

OFFICE OF NAVAL RESEARCH

PUBLICATIONS / PATENTS / PRESENTATIONS / HONORS REPORT

for

1 October 1983 through 30 September 1984

for

Contract N000114-84-C-0193

Task No. NR 384-936

Study of Optical Sound Generation and Amplification

Henry E. Bass, Lawrence A. Crum and F. Douglas Shields

Physical Acoustics Research Laboratory

The University of Mississippi
University, Mississippi 38677

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PAPERS SUBMITTED TO REFERRED JOURNALS
(not yet published)

Richard M. Detsch and Henry E. Bass, "Sound Amplification from Controlled Excitation Reactions: Experimental Observations in Chemically Reacting H_2/Cl_2 Mixtures," Journal of the Acoustical Society of America, Co-sponsored by the National Science Foundation.

F. Douglas Shields, "Propagation of Sound Through a Gas with an Overpopulation of Excited Vibrational States," Journal of the Acoustical Society of America, expected publication date: December 1984.

R.A. Roy, A.A. Atchley, L.A. Crum, J.B. Fowlkes and J.J. Reidy, "A Precise Technique for the Measurement of Acoustic Cavitation Thresholds, and Some Preliminary Results," Journal of the Acoustical Society of America, Co-sponsored by the National Science Foundation.

G.M. Hansen, "Mie-scattering as a Technique for the Sizing of Air Bubbles," Applied Optics, Co-sponsored by the National Science Foundation.

PAPERS PUBLISHED IN REFEREED JOURNALS

Richard M. Detsch and Henry E. Bass, "Vibrational Relaxation of SF₆ Mixtures with Cl₂ and H₂," Journal of the Acoustical Society of America, Vol. 75, pages 1635-1637² (1984).

Henry E. Bass and Hai-Xing Yan, "Pulsed Spectrophone Measurements of Vibrational Energy Transfer in CO₂," Journal of the Acoustical Society of America, Vol. 74, pages 1817-1825 (1983), Co-sponsored by The University of Mississippi.

Lawrence A. Crum, "Rectified Diffusion," Ultrasonics, Vol. 22, pages 215-224 (1984).

L.A. Crum and A. Prosperetti, "Erratum and Comments on Nonlinear Oscillation in Liquids: An Interpretation of Some Experimental Results," Journal of the Acoustical Society of America, Vol. 75, 1910-1212 (1984).

L.A. Crum and J.R. Brosey, "The Effect of Polymer Additives on the Acoustic Cavitation Threshold of Water," Journal of Fluids Engineering, Vol. 160, 99-104 (1984), Co-sponsored by the National Science Foundation.

BOOKS (AND SECTIONS THEREOF) SUBMITTED FOR PUBLICATION

N/A

BOOKS (AND SECTIONS THEREOF) PUBLISHED

N/A

PATENTS FILED

N/A

PATENTS GRANTED

N/A

INVITED PRESENTATIONS AT TOPICAL OR
SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

L.A. Crum, "Some Effects Associated with Large Amplitude Ultrasonic Waves in Liquids," an invited presentation to the American Physical Society for a Special Session on "Applications in Physics," Washington, D.C., April 23-26, 1984, Co-sponsored by the National Science Foundation and the North Atlantic Treaty Organization.

HONORS/AWARDS/PRIZES

Mr. Anthony Atchley has been unofficially notified that he will be offered the prestigious Hunt Fellowship in Acoustics for 1985-86.

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